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(54) Electrically propelled vehicles, and a combined energy source and energy reservoir therefor

(57) A combined energy source and energy reservoir for an electrically-propelled vehicle comprises a flywheel 1 which is also an electrochemical cell or battery of cells.

The flywheel-battery serves the electrical traction needs of the vehicle whilst also being adapted to conserve kinetic energy of the vehicle, when the vehicle is braked. The spinning motion of the flywheel-battery also aids the electrochemical action of the battery. The battery is supplied through inlet/outlet 8 by fuel consisting of a slurry of metal particles in an electrolyte which acts in conjunction with air electrodes 5 on the surface of the flywheel-battery to produce the electrochemical effect.

FIG. 1

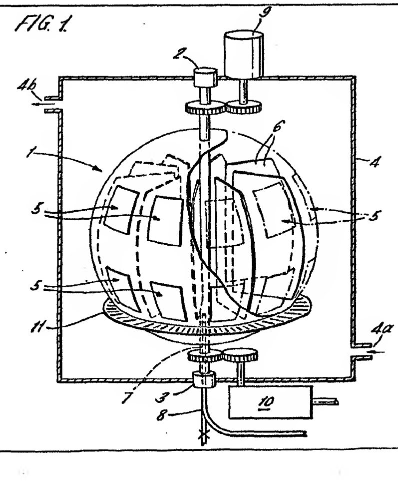

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FIG. 1.

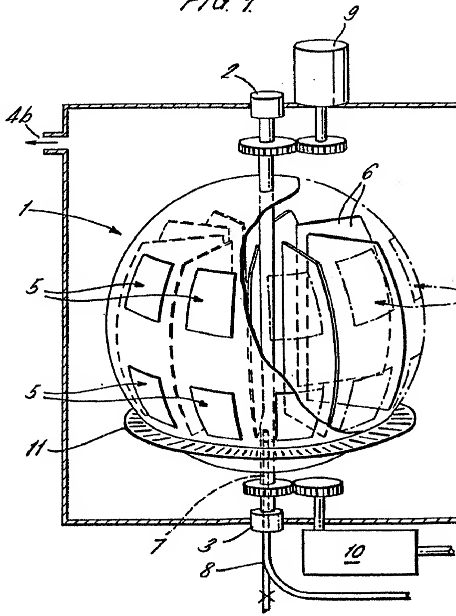

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FIG. 2.

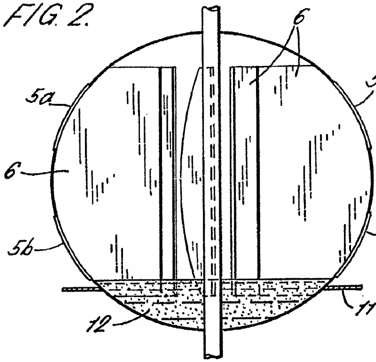
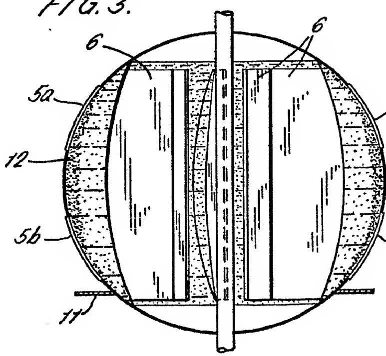


FIG. 3.



SPECIFICATION

Electrically propelled vehicles, and a combined energy source and energy reservoir therefor

This invention relates to electrically-propelled vehicles, particularly although not exclusively road vehicles, and a combined energy source and energy reservoir therefor.

The electric vehicle as at present conceived may consist of a electrochemical battery or batteries of prismatic or cylindrical configuration, a chassis, a transmission system, an electric motor and allied electric controls.

The battery of such a vehicle, to be economic, requires to be rechargeable electrically or mechanically, light in weight and able to give substantial power output, as well as having a high energy potential, where range is an important factor.

A number of possibilities for such a vehicle have been tried, and others are in the course of development. Of the existing available electrochemical couples to supply motive power, the Lead Acid couple is a leading contender as are other ambient temperature rechargeable couples such as Nickel-Zinc, Nickel-Iron and Nickel-Cadmium. All of these, however, have the disadvantages of limited power density, Energy density, Specific power, or specific energy, by virtue of the high atomic mass of the materials used, their availability and the efficiency of the electrochemical action as compared to their theoretical potential.

Primary batteries, on the other hand, generally use materials of lower atomic mass, such as Carbon, Zinc, Lithium or Hydrogen. At the same time, Primary batteries generally offer greater specific energy but are limited in use by the fact that the electrochemical action is not readily reversible, thus involving greater cost.

One approach in the development of rechargeable batteries has been to employ temporary environmental conditions such as high or low temperatures or high or low pressures within the battery array of cells, to obtain the benefits of special characteristics that some materials demonstrate under these special conditions. Such batteries working at high temperatures are Sodium-Sulphur and Lithium-Iron Sulphide, whilst others working at high pressures employ the Nickel-Hydrogen and Silver-Hydrogen couples. It has been found that materials working under these special conditions have advantageous properties which enhance the performance of the rechargeable battery. However, apart from environmental hazards that can be created by using these special conditions there are technical problems which have yet to be resolved. In addition, the cost of manufacture of long-life rechargeable batteries working under these conditions has yet to be shown to be economic.

Other electrochemical possibilities that have been investigated employ Metal-Air batteries in which the metal is oxidised to the metal oxide, with ensuing electrical output. Couples employed are, for example, Zinc-Air, Aluminium-Air, Magnesium-Air, Lithium-Air and Iron-Air. Other couples use the reaction of water, or other aqueous media, with a metal or reactive metal compound to provide an electrochemical effect.

Other motive power electric vehicle electrochemical systems employ fuel cells, in which a fuel reacts with a gas such as oxygen to yield an electric output, in place of combustion. Such batteries may work under special conditions of temperature and pressure to gain the effect of electric output. The Fuel Cell has a number of advantages, including efficiency and fast rechargeability by the process of refuelling. To date, however, the life and power/energy potential of such systems has been limited.

A number of Hybrid systems have been proposed for Electric Vehicles, in order to gain range and improve urban cycle performance. Four examples of such proposals are:—

(i) A vehicle employing a battery and an internal combustion engine;

(ii) A vehicle employing a battery and a fuel cell;

(iii) A vehicle employing a battery of high energy potential and also a battery able to give high power when required; and

(iv) A vehicle employing a battery and a flywheel.

In electric vehicle technology to date the vehicle has tended to be treated as a set of separate components, i.e. wheels, motor, chassis and battery. According to the present invention, however, the vehicle is treated more as an interactive system of components.

According to the present invention there is provided a combined energy source and energy reservoir for an electrically-propelled vehicle, comprising an electrochemical cell or battery of cells to be carried by the vehicle, which cell or battery, in whole or in part, forms the whole or a part of a rotatable mass which mass is adapted to act as a flywheel to conserve kinetic energy of the vehicle when the translational speed of the vehicle is reduced. Also within the scope of this invention are electric vehicles whenever equipped with such a combined energy source and energy reservoir.

The concept of constructing a battery and a flywheel, wherein the flywheel converts the kinetic energy of translation of the vehicle by the braking action of the vehicle into kinetic energy of spinning motion and where the kinetic energy of translation may be regained by means of a continuously variable drive mechanism, to power the vehicle on the acceleration mode, has the advantage of saving

weight to be carried by the vehicle, as compared with a separate battery and flywheel, and also possibly a saving in cost.

As some 50% of a vehicle's energy is usually lost by braking in the urban cycle such a combination of transfer of vehicle motion kinetic energy into a flywheel on braking has a significant advantage. Thus, a 50Kg flywheel may retain, say, 0.3KWh of kinetic energy to be used in the acceleration or hill climbing mode.

According to one aspect of the present invention the electrochemical cell or battery is rechargeable *in situ* in the vehicle, in which case the electrochemical couple may, for example, be Lead-Acid, Nickel-Zinc, Nickel-Iron or Nickel-Cadmium.

The rotatable mass may contain a ferritic material which is adapted to act as an, or part of an, armature of a dynamo or alternator which in turn is adapted to recharge the cell or battery *in situ*. Additionally, or alternatively, the ferritic material may be adapted to act as part of an electric motor or linear accelerator to give, or contribute to, the driving motion of the vehicle.

Means may also be provided for using grid-based electrical power to spin-up the rotatable mass prior to locomotive use of the vehicle. Thus, for example, mains power may be applied to the stationary vehicle by means of a linear inductive field effect upon an aluminium disc attached to the rotatable mass, through field coils not in direct contact with the rotatable mass.

In another aspect of the invention, an electric motor may be provided which is adapted to be operated by electrical power produced by the battery and which is linked to the rotatable mass so as to rotate it. By this means, electrical power produced by the battery can be used to assist in the spin-up of the rotatable mass prior to locomotive use of the vehicle.

The use of a cell or battery as a flywheel may enable the natural force of angular motion to be used to cause enhancement of the electrochemical action, whereby the power and/or energy output of the cell or battery is increased. Thus, the use of said natural force may be to reduce the need to resort to high temperatures or pressures. Optionally the force may also be used to vary the spacing between electrodes in the cell or battery or to enable a particulate electrode to be compacted or distributed to an operative position.

As an alternative to a cell or battery which is rechargeable *in situ*, a cell or battery may be employed which is not rechargeable but in which means are provided for supplying fresh active electrochemical material to replace material used up during the electrochemical action of the cell or battery. Such a cell or battery may, for example, be a fuel cell or battery of fuel cells, or, for example, a cell or battery using a metal/oxygen couple.

Where one of the electrodes of the cell or each electrochemical cell of the battery is an air or oxygen electrode these are desirably situated on the exterior of the rotatable mass so that the efficiency of the battery benefits from the flow of air or oxygen past the electrode due to the rotation of the cell or battery.

When the second electrode is a metal electrode the metal is preferably zinc, lithium, aluminium, magnesium or iron, or an alloy of two or more of said metals.

In a preferred embodiment of the invention the second electrode is provided by a dispersion of active particulate material in an electrolyte contained within the rotatable mass. In this case radially oriented insulating partitions may be provided within the rotatable mass so that when the mass is rotated the dispersion of active material is separated into separate cells each having at least one adjacent oxygen or air electrode in the exterior of the rotatable mass.

When oxygen or air electrodes are used on the exterior of the rotatable mass the mass is desirably contained within an enclosure having a controlled atmosphere.

Following is a description by way of example of an embodiment of a combined energy source and energy reservoir for an electrically-propelled vehicle in accordance with the invention.

In the accompanying drawings:

Figure 1 is a schematic view of a combined energy source and energy reservoir in accordance with the invention;

Figure 2 is diametrical vertical section through the rotatable mass of Fig. 1 when the mass is stationary;

Figure 3 is a diametrical vertical section through the rotatable mass of Fig. 1 when the mass is rotating and when the battery becomes operative;

Referring firstly to Fig. 1, a hollow flywheel battery 1, approximately a hollow sphere in shape, 1.3 metres in height and 1.2 metres in diameter, is suspended so that it can rotate about a vertical axis between upper and lower bearings 2,3 mounted in the walls of an enclosure 4. The casing of the battery is made of plastics or plastics-coated metal. The enclosure is provided with an inlet 4a and an outlet 4b for controlling the humidity of the air adjacent the air electrodes of the battery. On the exterior of the flywheel battery are metal plates 5 forming the air extrodes. Extending inwardly radially from the inside wall of the battery are nine equidistant insulating vanes or partitions 6. Mounted through the lower bearing 3 of the insulated axle 7 of the flywheel battery is a fuel inlet/outlet 8 for supplying fuel to the interior of the battery and for withdrawing unwanted material from the battery. The fuel is in the form of particu-

late metal, usually iron, zinc or aluminium, suspended in an electrolyte. Means, not shown, are provided for pumping fuel from a storage tank in the vehicle into the battery.

At the top of the battery a D.C. electric motor 9 supplied by electricity fed from the battery is geared to the axle of the battery so that it is able to drive the axle 7 of the battery. At the bottom of the battery the axle 7 is geared by means of a conventional variable drive system 10 to the drive shaft of the vehicle.

Mounted at the bottom of the battery is a ring of aluminium 11 which is to operate with a linear induction motor (not shown) fed from the mains grid in order to spin-up the flywheel battery before locomotive use of the vehicle.

Now that the main physical features of this vehicle propulsion system have been indicated, the manner in which it works will now be described together with further details of its construction, with reference to Figs. 2 and 3 of the drawings.

The partitions 6 inside the flywheel battery in fact divide the interior of the flywheel battery into nine segment cells when the battery is brought into use. Each of these cells has a corresponding upper and lower air electrode, 5a and 5b respectively, i.e. two air electrodes per segment cell.

When the flywheel battery is at rest, fuel introduced through the fuel inlet at its bottom will merely rest as a pool 12 at the bottom of the interior of the battery as shown in Fig. 2. However, when the flywheel battery is spun, the slurry of metal particles 12 is redistributed onto the walls of the inside of the battery as shown in Fig. 3. Furthermore, the centrifuging action of the spin tends to bring the metal particles out of suspension so that they press against the inside surfaces of the air electrodes. The spin also has the desirable effects firstly of causing a high air flow rate over the air electrodes and also that the redistribution of the metal particle suspension fuel increases the angular momentum of the flywheel battery as a whole. As the rate of spin increases the pressure of the metal suspension on to the air electrodes also increases which aids the performance of the electrochemical action and an intimate metal matrix is formed which is equivalent to the formation of a semi-solid battery electrode.

Electrically, the segment cells of the battery which are formed, as explained above, are connected by the oxygen electrodes being connected with one another on the exterior of the flywheel battery with a power take-off from them, and inside the battery each vane or partition is provided with a strip of metal foil as a conductor in contact with the particularly metal electrode close to the air electrode, these strips being interconnected and provided with the second power take-off. Thus each segment cell of the battery is connected in series, and the power output is fed to the D.C. motor 9 which is able to drive the spinning flywheel battery, and maintain the flywheel battery at a desired spin rate. In fact, the system will provide electrical power in excess of that required to maintain the spin rate and the surplus power is used for other electrical needs of the vehicle.

A vehicle fitted with the combined energy source and energy reservior of the present invention is made operative by the following method. Firstly, the flywheel battery is spun-up at a base station using a linear induction motor powered by the mains grid and acting on the aluminium ring 11. Fuel is also pumped into the flywheel battery, if not already present.

The flywheel battery is able to hold the equivalent, in electrical terms, of up to 1KWh of kinetic energy of spinning motion. The use of a 13 amp grid supply of 240 volts might be expected to entail a spin-up time of about 20 minutes. However, since the flywheel battery will commence to supply electrical power itself after it has started to spin, the spin-up time is actually of the order of no more that 10 minutes.

When it is desired to set the vehicle in motion there are two sources of power available, firstly the kinetic energy store in the flywheel battery and, secondly, electrochemical power drawn from the battery and operating the D.C. motor. Thus, using both sources of power the vehicle can be accelerated at any variable rate by means of the conventional variable drive 10 to the drive shaft of the vehicle. On braking and decelleration of the vehicle the variable drive acts in reverse in translating the need to brake into added spin or recovered spin of the flywheel battery.

The ability of the vehicle to retain energy in two forms yet in the same unit has many advantages in cost, weight and space.

In the urban cycle with many stop-starts the conventional battery-powered vehicle is very inefficient and short-ranged, due to loss of energy on braking. With the present invention the energy is conserved and the range therefore increased. Furthermore, the spin of the battery aids its electrochemical performance. Additionally, the mass of fuel added to the flywheel battery is set at a maximum in the urban cycle so that as much as possible of the deacceleration energy is stored in the largest possible spinning mass. On the other hand, in a rural long-range application constant velocity is achieved by a variable weight control of the input of the acting material into the flywheel battery and the direct application of the electrochemical action to the D.C. motor to drive the flywheel and variable drive.

To give some specific operational figures for the above specific system, using an aluminium-air flywheel battery in a vehicle having a total mass of 2,800 lbs and a range of 250

miles, 100 lbs of fuel are used consisting of 32 lbs of aluminium powder dispersed in an electrolyte. The total weight of the flywheel battery including fuel is 200 lbs. Such a system yields a cruise voltage of 12 volts and gives the vehicle a power of approximately 38 KW and energy of approximately 70 KWh. The aluminium-air battery has the disadvantages that non-conductive aluminium oxide tends to accumulate and the air electrodes need to be operated in an enclosure at 40 to 50°C. An iron-air battery has advantages in that, although more cells per battery are required, the reaction products are more conductive and can be stirred within the flywheel battery by fixed magnets positioned outside the battery, and, additionally, iron has a higher atomic mass than aluminium.

CLAIMS

1. A combined energy source and energy reservoir for an electrically-propelled vehicle, comprising an electrochemical cell or battery of cells to be carried by the vehicle, which cell or battery, in whole or in part, forms the whole or a part of a rotatable mass which mass is adapted to act as a flywheel to conserve kinetic energy of the vehicle when the translational speed of the vehicle is reduced.

2. A combined energy source and energy reservoir as claimed in Claim 1 wherein the cell or battery is rechargeable *in situ* in the vehicle.

3. A combined energy source and energy reservoir as claimed in Claim 2 wherein the rotatable mass contains a ferritic material which is adapted to act as an, or part of an, armature of a dynamo or alternator which in turn is adapted to recharge the cell or battery.

4. A combined energy source and energy reservoir as claimed in any one of the preceding claims which is adapted to provide an increase in the translational speed of the vehicle by conversion of the kinetic energy of rotation of the rotatable mass.

5. A combined energy source and energy reservoir as claimed in any one of the preceding claims wherein the rotatable mass contains a ferritic material adapted to act as part of an electric motor or linear accelerator to give, or contribute to, the driving motion of the vehicle.

6. A combined energy source and energy reservoir as claimed in any one of the preceding claims wherein means are provided for using grid-based electrical power to spin-up the rotatable mass prior to locomotive use of the vehicle.

7. A combined energy source and energy reservoir as claimed in any one of the preceding claims which additionally comprises an electric motor which is adapted to be operated by electrical power produced by the cell or battery and which is operably linked to the rotatable mass so as to rotate the rotatable mass.

8. A combined energy source and energy reservoir as claimed in any one of the preceding claims wherein rotation of the rotatable mass causes enhancement of the electrochemical action in the cell or battery whereby the power and/or energy output of the cell or battery is increased.

9. A combined energy source and energy reservoir as claimed in Claim 8 wherein the spacing between electrodes in the cell or battery is varied as a result of rotation of the cell or battery.

10. A combined energy source and energy reservoir as claimed in Claim 1 and any one of Claims 4 to 9 wherein the cell or battery is not rechargeable *in situ* and wherein means are provided for supplying fresh active electrochemical material to the cell or battery to replace material used up during the electrochemical action of the cell or battery

11. A combined energy source and energy reservoir as claimed in Claim 10 wherein one of the electrodes of the cell or each electrochemical cell of the battery is an air or oxygen electrode.

12. A combined energy source and energy reservoir as claimed in Claim 11 wherein the air or oxygen electrodes are situated on the exterior of the rotatable mass.

13. A combined energy source and energy reservoir as claimed in Claim 11 or Claim 12 wherein the second electrode is a metal electrode.

14. A combined energy source and energy reservoir as claimed in Claim 13 wherein the metal of the second electrode is zinc, lithium, aluminium, magnesium or iron, or an alloy comprising one or part of said metals.

15. A combined energy source and energy reservoir as claimed in any one of Claims 10 to 14 wherein the second electrode is provided by a dispersion of active particulate material in an electrolyte contained within the rotatable mass.

16. A combined energy source and energy reservoir as claimed in Claim 15 wherein radially oriented insulating partitions are provided with the rotatable mass so that when the mass is rotated the dispersion of active material is separated into separate cells each having at least one adjacent oxygen or air electrode on the exterior of the rotatable mass.

17. A combined energy source and energy reservoir as claimed in any one of Claims 12 to 16 wherein the rotatable mass is contained within an enclosure having a controlled atmosphere.

18. A combined energy source and energy reservoir substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

19. An electrically-propelled vehicle when-

ever equipped with a combined energy source and energy reservoir as claimed in any one of the preceding claims.

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